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RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	06/28/99	Rewritten and reformatted to support LIR 220-03-01. Superseded Facilities Engineering Standards, Volume 7, Electrical, Manual Rev 15, 6/26/98.	David W. Powell, *PM-2*	Dennis McLain, *FWO-FE*
1	11/18/02	General revision and addition of endnotes. Replaces Subsections: 212, 246.6, 261, 262, and 263.	David W. Powell, *FWO-SEM*	Kurt A. Beckman, *FWO-SEM*

D5090 OTHER ELECTRICAL SYSTEMS

1.0 GENERAL

Requirements and guidance in section D5000 of the LANL Engineering Manual (LEM) apply to this section.

2.0 ENGINE-GENERATOR SYSTEMS

2.1 General

Furnish, install, and acceptance-test engine-generator systems (EGS) using the following codes, standards and this section:

1. EGSA 101P, *Engine Generator Sets Performance Standard*.[1]
2. EGSA 100B, *Engine Cranking Batteries Used with Engine Generator Sets.*
3. EGSA 100C, *Performance Standard for Battery Chargers for Engine Starting Batteries and Control Batteries (Constant Potential Static Type)*.
4. IEEE Std 446, *IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications.*
5. NFPA 70, *National Electrical Code* (NEC).
6. NFPA 110*, Standard for Emergency and Standby Power Systems.*
7. NFPA 37*, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*
8. NFPA 30*, Flammable and Combustible Liquids Code.*
9. LEM D5000 heading Additional Requirements for Nuclear Facilities.
10. UL 2200, *Standard for Stationary Engine Generator Assemblies* (for systems rated 600V and less*)*

2.2 Minimum Rating

A. Provide EGS capable of supplying the connected loads plus not less than 20 percent future load growth at an altitude of 7500 feet and an ambient temperature of 100 F.[2]

B. EGS must be rated so the two-cycle voltage dip will not exceed 25 percent[3] during the worst case motor starting scenario.

C. If EGS is used to back-up UPS loads it must include an isochronous governor and an UPS compatible voltage regulator. EGS must be capable of simultaneously supporting the UPS load, UPS battery charging, and UPS room cooling. *Coordinate EGS selection with UPS and EGS manufacturers.*

D. Provide EGS of the NFPA 110 type, class, and level to meet the User's operational needs for emergency or standby power and to meet the requirements in Table D5090-1.

Table D5090-1: EGS Classifications

Load	NFPA 110 Type[4]	NFPA 110 Class[5]	NFPA 110 Level[6]
Safety Class System	10*	96[7]	1
Safety Significant System	10*	96[7]	1
Security System	10*	24[8]	2
Life Safety System	10*	96[7]	1
Critical Telecommunications System	10*	24[8]	2
Other Systems	60	8	2

* Some systems may require uninterrupted power at the utilization equipment. In those cases the NFPA Type is the maximum time the UPS is without acceptable input power. Refer to the UPS Systems heading in Section D5090.

2.3 Energy Source[9]

A. Base EGS energy source (fuel) type selection on the following requirements and guidance:

1. Level 1 systems: Diesel.[10]
2. *Level 2 systems: Diesel or natural gas.*

B. Provide fuel system with adequate capacity to meet the NFPA 110 Class requirements plus capacity for required acceptance testing, periodic exercising, and maintenance and operational testing.

C. Provide fuel systems that meet the requirements of NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*. Meet specific requirements in the following codes as applicable:

1. NFPA 54, *National Fuel Gas Code*.
2. NFPA 30, *Flammable and Combustible Liquids Code*.

D. Provide NRTL listed tanks for and suitable secondary containment for liquid fuel systems.

1. *Single-wall tanks may be installed in concrete containment structures or vaults that also facilitate visual inspection for tank leaks.*
2. *Double wall tanks with adequate mechanical and fire protection and suitable leak detection systems may be installed above grade.*

2.4 Transfer Switch

A. In addition to the requirements of NFPA 110[11], provide the following for transfer switches:

1. Bypass-isolation type transfer switches for all permanent installations.[12]

2. Time delay on start of engine-generator: 1 second.[13]
3. Time delay on retransfer to normal source: 30 minutes.[14]
4. Transfer switch operations counter.[15]
5. In-phase monitor for motor loads.[16]
6. 4-pole transfer switch for 3-phase, 4-wire systems.[17]

B. Provide transfer switches that are NRTL listed to UL 1008 and are selected and protected according to the short circuit and over-voltage considerations outlined in IEEE Std 446.[18]

2.5 Starting System

A. Provide starting battery system as required by NFPA 110 and the following:

1. Lead-acid type battery,[19] not valve-regulated type,[20] which meets EGSA 100B.
2. Automatic battery charger, with equalize charge timer, that meets EGSA 100C.

B. Provide battery heater and crankcase heater for each outdoor installation.[21]

2.6 Remote Annunciation

A. For Level 1 systems provide the NFPA 110 required remote common alarm of engine generator malfunction[22] at the following locations:

1. At a location in the facility that is outside the generator room and observable by personnel.[23]
2. A location that is continuously staffed; *this may be in another building that has control over the system or at a central monitoring facility*.

B. For Level 2 systems provide the NFPA 110 required remote common alarm of engine generator malfunction [22] at a location in the facility that is outside the generator room and observable by personnel. [23]

2.7 Noise Control

Use the following noise control systems as appropriate to limit EGS noise to a maximum of 70 dB(A) measured at ground level 50 feet in any direction from the center of the generator set:

1. Critical type muffler(s) providing 25 to 35-dB attenuation in the 125 to 1000 Hz range.
2. Exhaust discharge pointed up.
3. Sound deflecting barrier in front of radiator discharge opening.[24]
4. Sound-attenuating louvers on air-intake opening(s) into generator room.
5. Intake silencer for turbo-charged engines; *may be combined with air cleaner*.
6. Vibration isolation for installations inside buildings.
7. Noise attenuating housings or sound barriers for outdoor installations.[25]

2.8 Seismic

A. Level 1 EGS systems must be capable of performing their intended function during and after a design basis seismic event.[26]

B. Design and construct all EGS equipment support or sub-support systems so that they can withstand static or anticipated seismic forces, or both, in any direction, with the minimum force value used being equal to the equipment weight.[27]

C. Provide bolts, anchors, hangers, braces, and other restraining devices to limit earthquake-generated differential movements between the EGS nonstructural equipment and the building structure. Maintain the degree of isolation required for vibration and acoustical control of the EGS equipment and other equipment. [27]

D. Brace suspended items such as piping, conduit, ducts, and other auxiliary equipment related to the EGS in two directions to resist swaying and excessive movement in an earthquake. [27]

E. Design battery racks for EGS equipment and electrical items or related auxiliaries, or both, to resist internal damage and damage at the equipment supports resulting from earthquake-generated motion. Provide battery racks that are capable of withstanding seismic forces equal to the supported weight in any direction. Restrain batteries to their support to prevent vibration damage, and provide electrical interconnections with adequate slack to accommodate all relative deflections. [27]

F. Mount transfer switch enclosures so that the anchors and support structures can withstand static forces equal to the anticipated seismic shock in any direction. Provide transfer switch components of the type that resist malfunction during dynamic excitation and are designed to resist the anticipated seismic shock. [27]

G. Where possible, provide EGS equipment and associated cooling systems and controls mounted on a single frame. Rigidly attach the frame to its foundation so that its anchorage can withstand static forces equal to the equipment weight in any direction. Where engine generator sets and associated cooling systems' controls cannot be mounted as an integral unit, secure each component to meet the above floating requirements. Equipment not using the preferred rigid mounting shall have vibration isolators with restraints capable of withstanding static forces equal to twice the weight of the supported equipment in any direction. In addition, interconnecting power, fuel, and cooling lines shall be provided with adequate flexibility to allow maximum anticipated excursions without damage. [27]

H. Mount appendages to the EGS equipment, such as day tanks, to withstand static forces equal to the anticipated seismic shock in any direction. [27]

2.9 Load Bank

A. Provide a permanently installed[28] load bank for a Level 1 or Level 2 EGS under either of the following circumstances:

1. The steady-state kW of the facility load connected to the EGS is less than 30% of the EGS nameplate kW rating.
2. The User is reluctant to use the facility load for the NFPA 110 required monthly exercising of the EGS.

B. Use a unity power factor load bank equal to not less than 30 percent of nameplate kW rating or greater percentage if recommended by the engine-generator manufacturer.[29]

2.10 Generator Output

A. Provide an accessible circuit breaker in the generator output circuit.

B. Circuit breaker shall be the NEC required disconnecting means for the generator.[30]

C. Circuit breaker shall provide overcurrent protection for the generator and the output conductors.[31]

D. Provide ground fault detection and alarm system if the generator circuit breaker rating exceeds 1000 amperes on 480Y/277V systems.[32]

E. Provide conductors from the generator terminals to the circuit breaker terminal with an ampacity not less than 115 percent of the generator nameplate rating.[33]

2.11 Grounding

A. Bond the EGS frame to the main grounding electrode ground bar or to a main grounding electrode ground bar extension using 4/0 AWG ground cable and IEEE 837 compression lugs.

B. Bond the grounded conductor to the generator frame using a main bonding jumper sized per Table 250.66.[34]

2.12 Acceptance Testing

A. Perform acceptance testing of EGS as required by NFPA 110.[35]

1. Provide advance notification of acceptance testing to the LANL Electrical AHJ.[36]
2. Tests shall be performed by qualified personnel such as the EGS manufacturer's factory-trained technicians or technicians that are certified in accordance with ANSI/NETA ETT-2000, *Standard for Certification of Electrical Testing Technicians*.
3. Make a detailed record of acceptance test results on a form suitable for the purpose.
4. Provide analysis and recommendations with the acceptance test report.

B. Provide copies of the acceptance test report and all certifications required by NFPA 110 to the LANL electrical AHJ and to the Facility Manager.

3.0 UPS SYSTEMS

3.1 General

This heading addresses permanently installed uninterruptible power supply (UPS) systems rated 1 kVA and larger. *It is anticipated that guidance will be added later addressing rack-mounted UPS equipment and plug connected commodity UPS equipment.*

3.2 UPS Selection

A. Furnish, install, and acceptance-test UPS systems to meet the User's operational needs for uninterruptible, computer-grade power in conformance to the following codes and standards and this Section:

1. IEEE Std 446, *IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*
2. IEEE Std 493, *IEEE Recommended Practice for Design of Reliable Industrial and Commercial Power Systems*
3. IEEE Std 944, *IEEE Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations*
4. IEEE Std 1100, *IEEE Recommended Practice for Powering and Grounding Electronic Equipment.*
5. NFPA 70, *National Electrical Code* (NEC)
6. NFPA 111, *Stored Energy Emergency and Standby Power Systems.*
7. LEM D5000 heading Additional Requirements for Nuclear Facilities.

B. Provide on-line UPS systems[37] (defined as UPS that continuously derive output alternating current power from direct current or high frequency alternating current).

C. Select static (Refer to Figure D5090-1) or rotary (Refer to Figure D5090-2) power conversion UPS equipment and UPS battery type based on a 20-year life cycle cost analysis. *Consider the following factors as applicable:*

1. *Initial cost of UPS, battery, and directly associated building floor space (e.g., UPS room, battery room) and support systems (e.g., UPS cooling, battery room ventilation, and special plumbing).*
2. *UPS energy costs including those of directly related building support systems.*
3. *Scheduled maintenance costs for UPS, batteries, and directly associated building floor space and support systems.*
4. *Predicted repair and replacement costs for UPS components, batteries, and directly associated building support systems.*

Figure D5090-1: Typical Static UPS System

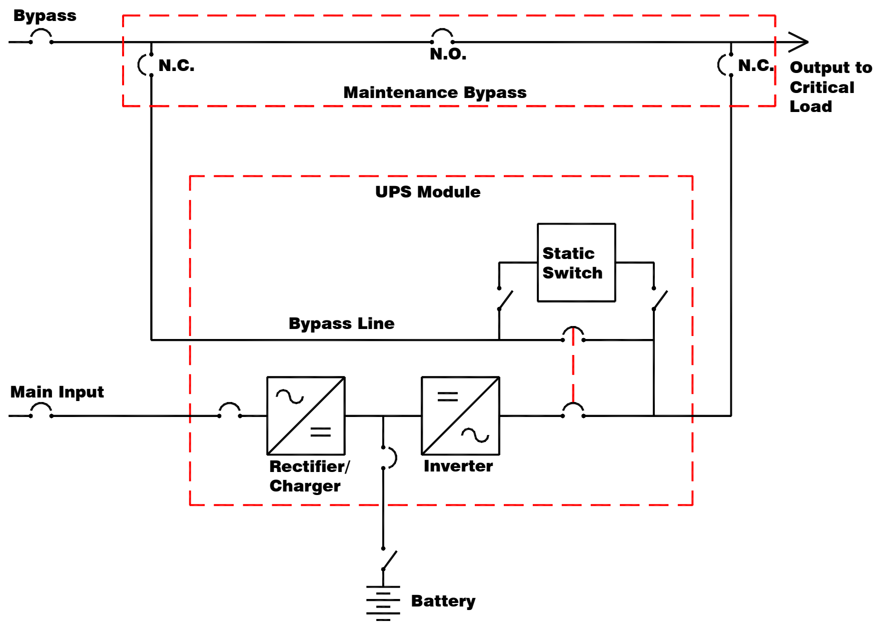
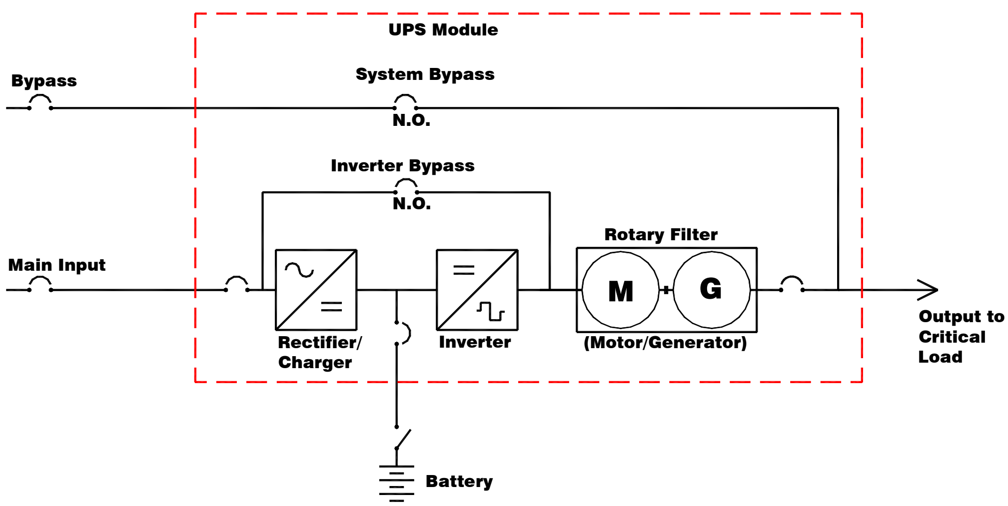


Figure D5090-2: Typical Rotary UPS System



D. De-rate UPS capacity for operation at 7500-ft elevation: *93.5 percent is typical, but verify with manufacturer.*

E. Select UPS systems based on the following load data:

1. Total steady-state load[38] calculated in accordance with the NEC.[39]
2. Load power factor. [38]
3. Inrush requirements of the load. [38]
4. Load linearity. [38]
5. Include not less than 20 percent future load growth capacity.

F. Provide UPS systems of the NFPA 111 type, class, and level to meet the User's operational needs for uninterruptible, computer-grade power and the requirements in Table D5090-2.

Table D5090-2: UPS Classifications

Load	NFPA 111 Type[40]	NFPA 111 Class[41]	NFPA 111 Level[42]
Safety Class System	0	0.25 with generator backup*	1
Safety Significant System	0	1.5 without generator backup 0.25 with generator backup	1
Security System	0	8 without generator backup[43] 0.25 with generator backup	2
Other (data processing, telecommunications, etc)	0	0.25 without generator backup 0.083 with generator backup	3

*Provide engine-generator backup for UPS systems that support Safety Class Systems.[44]

G. Use UPS manufacturers with emergency response capabilities as follows:[45]

1. Level 1 systems 4 hours or better.
2. Level 2 systems: 8 hours or better.
3. Level 3 systems: 12 hours or better.

3.3 UPS Survivability

A. Level 1 and Level 2 UPS systems must be capable of performing their intended functions during and after a design basis event.[46]

B. Require that the manufacturer of a Level 1 UPS system demonstrate seismic qualification of the system, including battery.[46] *One or more of the following methods may be used to demonstrate seismic qualification:*

1. *Predict the equipment seismic performance and response to a seismic event by dynamic analysis using conditions comparable to those predicted at the installation location.*
2. *Test the equipment under simulated seismic dynamic conditions comparable to those predicted at the installation location.*
3. *Use previous seismic qualification of the equipment and demonstrate applicability to the installation location.*
4. *Use documented performance of equipment during actual earthquakes and adequately demonstrate applicability of the data to the installation location.*

C. Install adequate seismic anchorage for UPS, batteries, and associated auxiliary equipment.

1. Design and construct all UPS equipment support or sub-support systems so that they can withstand static or anticipated seismic forces, or both, in any direction, with the minimum force value used being equal to the equipment weight.[47]

2. Provide bolts, anchors, hangers, braces, and other restraining devices to limit earthquake-generated differential movements between the UPS nonstructural equipment and the building structure. Maintain the degree of isolation required for vibration and acoustical control of the UPS equipment and other equipment. [47]
3. Brace suspended items such as piping, conduit, ducts, and other auxiliary equipment related to the UPS in two directions to resist swaying and excessive movement in an earthquake. [47]
4. Design battery racks for UPS equipment and electrical items or related auxiliaries, or both, to resist internal damage and damage at the equipment supports resulting from earthquake-generated motion. Provide battery racks that are capable of withstanding seismic forces equal to the supported weight in any direction. Restrain batteries to their support to prevent vibration damage, and provide electrical interconnections with adequate slack to accommodate all relative deflections. [47]

D. Do not locate UPS or batteries in a building basement that is subject to flooding.[48]

3.4 UPS Configuration

A. Select UPS system configuration using the following factors:

B. Provide bypass switches[49] based on the following requirements; refer to Figure D5090-1:

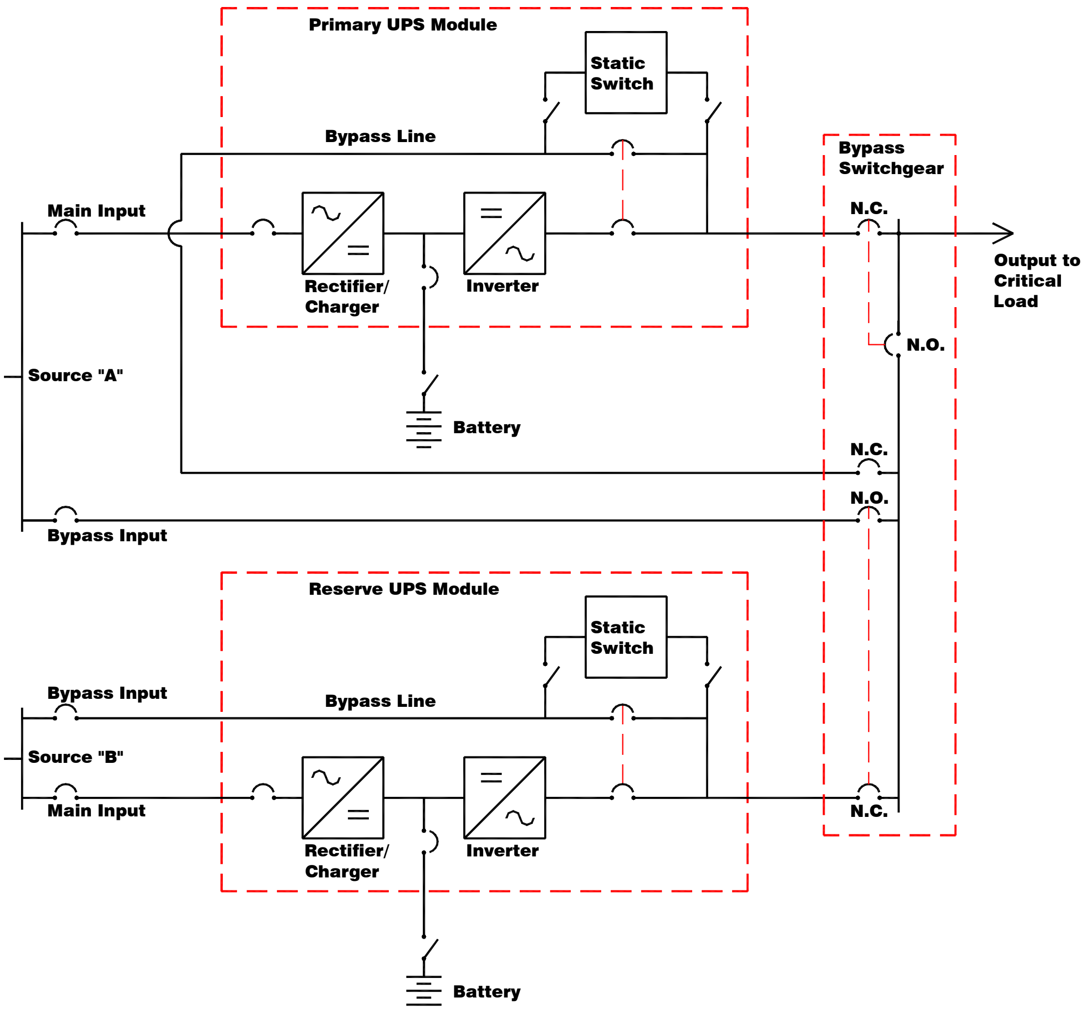
1. Provide UPS systems over 3.5 kVA with an automatic high-speed bypass switch.[50]
2. Provide three-phase UPS systems 12 kVA and over with a static bypass switch. [50]
3. Provide an external, manually operated, make-before-break maintenance bypass switch with padlocking provisions or plug control for UPS systems 2 kVA and over. [50] UPS module cabinet must be completely isolated and de-energized during maintenance.[51]
4. Install a separate bypass power input circuit for three-phase UPS systems 12 kVA and over.[52] *If possible the bypass circuit should be from a separate source (e.g. separate switchboard or even a separate primary circuit).*

C. Certain critical loads such as Safety Class systems or critical telecommunications loads may require increased system reliability beyond that which can be provided by a single UPS system. Determine reliability requirements and system capabilities using analysis methods described in IEEE Std 493.[53] Use the following special configurations to increase UPS system reliability:

1. Use two or more UPS modules in isolated redundant configuration for systems with "single-cord" loads (typical equipment with a single power supply).[54] *Each UPS module should have a dedicated battery.* Refer to Figure D5090-3.
2. Use two independent UPS systems serving a dual-bus distribution system for systems with predominantly "dual-cord" loads (special computer and telecommunications equipment with dual full-capacity internal power supplies feeding a common internal power bus).[55] *Each UPS module should have a dedicated battery.*

D. Design grounding schemes for UPS systems in accordance with recommendations in Chapter 8 of IEEE Std 1100.

Figure D5090-3: Typical Isolated-Redundant UPS System



E. If UPS batteries are installed in a separate battery cabinet or rack provide an external DC circuit breaker with padlocking provisions so the UPS cabinet can be completely isolated and de-energized during maintenance. [51] Refer to Figures D5090-1, -2, and –3.

F. Provide UPS battery monitoring systems[56] based on the following:

1. Each UPS module shall indicate UPS run time in minutes remaining and provide an alarm output contact at 5 minutes (field adjustable) remaining. [50] *Run time indication should be based on actual UPS load and battery discharge characteristic, not just a timer.*

2. Provide an NRTL-listed battery integrity monitoring system[57] that operates on a battery interconnection point basis to monitor individual cells for the following systems:
   - UPS systems over 225 kVA.
   - UPS systems with battery replacement cost over $20,000.
   - UPS systems serving Safety Class systems.

G. For UPS installed in computer rooms, provide remote EPO interface to shut down UPS AC output and to trip remote DC circuit breaker.[58]

H. Provide remote communications interface for UPS. UPS shall be Simple Network Management Protocol (SNMP) compatible and multi-computer interfaceable.

I. Three-phase UPS input current THD shall not exceed 10 percent.[59] *NOTE: Be cautious about excessive harmonic currents when installing multiple single-phase UPS systems in a facility!*

3.5 UPS Installation

A. Locate UPS considering security, fire separation, noise, floor loading, heat rejection, installation and replacement access, maintenance access, spare parts storage, and the following guidance:[60]

1. *UPS system 225 kVA and larger should be in a dedicated UPS room.*
2. *UPS louder than 60 dBA (measured one meter from the UPS) should not be located in any occupied space.*
3. *UPS serving Safety Class systems should be installed in a dedicated UPS room rated for design basis accident.*

B. Locate UPS battery considering floor loading, installation and replacement access, maintenance access, and the following guidance:[61]

1. *Batteries should be positively isolated from UPS electronics to prevent corrosion.*
2. *For a UPS system over 15 kVA, provide a separate battery compartment or cabinet with batteries on slide-out trays.*
3. *For a UPS system over 100 kVA, battery should be rack mounted in dedicated battery room; refer to the* Stationary Battery Power Systems *heading in this section for installation requirements.*
4. *Battery for a three phase UPS system serving Safety Class loads should be rack mounted in a dedicated battery room rated for design basis accident; refer to the* Stationary Battery Power Systems *heading in this section for installation requirements*

3.6 Building Auxiliary Systems

A. Provide building auxiliary systems required for proper operation of the UPS system.

B. Provide UPS room HVAC system considering operating temperature, continued operation, maintenance, and the following requirements:

1. Maintain a yearly average temperature of 77F with a 50F to 100F maximum range.[62]
2. Provide 30 percent efficiency air filtration.[63]
3. UPS room HVAC must continue while UPS operates on battery power to keep the ambient temperature below 100F[64]. *If the UPS is supported by a generator, the UPS room cooling can be powered by the generator.*
4. UPS room cooling must continue during HVAC system maintenance[65]—*this often necessitates a redundant HVAC system for the UPS room.*

C. Provide Class C portable fire extinguisher(s) at the UPS system. Consult with the LANL Fire Protection group to determine fire extinguisher size and placement.

D. Back-up engine-generator system, if used, must be selected for UPS support including an isochronous governor and a UPS compatible voltage regulator.[66] Generator must be capable of simultaneously supporting the UPS load, UPS battery charging, and UPS room cooling. *Coordinate selection with UPS manufacturer.*

E. Provide emergency lighting for the UPS and battery location.[67] *Use both battery-powered emergency lights and fluorescent luminaires connected to a UPS supplied circuit.*

F. Provide Category B transient voltage surge suppression on UPS input and bypass circuit(s).[68]

3.7 UPS System Acceptance Testing and Inspection

A. Perform complete acceptance testing and inspection of completed UPS system in accordance with NFPA 111[69], IEEE Std 944[70], and IEEE Std 1100[71].

1. Provide advance notification of acceptance testing to the LANL Electrical AHJ.
2. Tests shall be performed by qualified personnel such as the UPS manufacturer's factory-trained technicians or technicians that are certified in accordance with ANSI/NETA ETT-2000, *Standard for Certification of Electrical Testing Technicians*.
3. Make a detailed record of acceptance test results on a form suitable for the purpose.
4. Provide analysis and recommendations with the acceptance test report.

B. Provide copies of the acceptance test report and all certifications to the LANL electrical AHJ and to the Facility Manager.

4.0 Stationary Battery Power Systems

4.1 General

A. Provide stationary battery power systems (storage batteries, battery charging systems, and DC distribution equipment) as described in this heading to support loads for which the User requires uninterruptible DC power such as switchgear controls, alarm systems, inverters, and UPS systems.

1. Battery system requirements for small UPS systems with integral batteries are described under the UPS Systems heading.
2. Engine starting (cranking) battery systems are described under the Engine-Generator Systems heading.

B. Furnish, install, and acceptance-test stationary battery power systems in conformance to the following codes and standards and this Section:

1. NFPA 70, *National Electrical Code* (NEC)
2. NFPA 111, *Stored Energy Emergency and Standby Power Systems*
3. IEEE C2, *National Electrical Safety Code* (NESC)
4. IEEE Std 446, *IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*
5. IEEE Std 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*

6. IEEE Std 484, *IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*
7. IEEE Std 485, *IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications*
8. IEEE Std 946, IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations
9. IEEE Std 1187, *IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications*
10. IEEE Std 1189, *IEEE Recommended Practice for Selection of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications*
11. LEM D5000 heading Additional Requirements for Nuclear Facilities.

4.2 Battery Power System Survivability

A. Battery power systems serving Safety Class systems, Safety Significant components, life safety systems, switchgear control systems, or critical telecommunications systems, must be capable of performing the intended function during and after a design basis event. [46]

B. Require that the manufacturer demonstrate seismic qualification of the battery power system.[46] One, or a combination, of the following methods may be used to demonstrate seismic qualification:

1. *Predict the equipment seismic performance and response to a seismic event by dynamic analysis using conditions comparable to those predicted at the installation location.*
2. *Test the equipment under simulated seismic dynamic conditions comparable to those predicted at the installation location.*
3. *Use previous seismic qualification of the equipment and demonstrate applicability to the installation location.*
4. *Use documented performance of equipment during actual earthquakes and adequately demonstrate applicability of the data to the installation location.*

C. Install adequate seismic anchorage for battery power system components and associated auxiliary equipment.

1. Design and construct all battery power system equipment support or sub-support systems so that they can withstand static or anticipated seismic forces, or both, in any direction, with the minimum force value used being equal to the equipment weight. [47]
2. Provide bolts, anchors, hangers, braces, and other restraining devices to limit earthquake-generated differential movements between the battery power system nonstructural equipment and the building structure. Maintain the degree of isolation required for vibration and acoustical control of the battery power system equipment and other equipment. [47]
3. Brace suspended items such as piping, conduit, ducts, and other auxiliary equipment related to the battery power system in two directions to resist swaying and excessive movement in an earthquake. [47]

4. Design battery racks for battery power system equipment and electrical items or related auxiliaries, or both, to resist internal damage and damage at the equipment supports resulting from earthquake-generated motion. Provide battery racks that are capable of withstanding seismic forces equal to the supported weight in any direction. Restrain batteries to their support to prevent vibration damage, and provide electrical interconnections with adequate slack to accommodate all relative deflections. [47]

D. Do not locate battery power system in a building area that is subject to flooding. [48]

4.3 Battery Power System Configuration

A. Select battery power system components based on 20-year life cycle cost analysis. *Consider the following factors:*

1. *Initial cost of battery power system and directly associated building floor space (e.g. battery room) and support systems (e.g. battery room ventilation, and special plumbing).*
2. *Energy costs including those of directly related building support systems.*
3. *Scheduled maintenance costs for battery power system, and directly associated building floor space and support systems.*
4. *Predicted repair and replacement costs for battery power system, and directly associated building support systems.*

B. Select the battery type using the following guidelines:

1. *Systems serving loads over 225 kVA should have vented (flooded) lead-calcium cells with transparent jars and flame arrester vents.*
2. *Systems serving Safety Class loads should have vented (flooded) lead-calcium cells with transparent jars and flame arrester vents or fully redundant strings of valve regulated lead acid (sealed lead-calcium) batteries.*
3. *Valve regulated lead acid batteries may be used with non-Safety Class systems up to 225 kVA. NOTE: This type battery will need to be replaced at about 55-month intervals.*
4. *Nickel-cadmium batteries should be avoided due to hazardous waste disposal issues.*

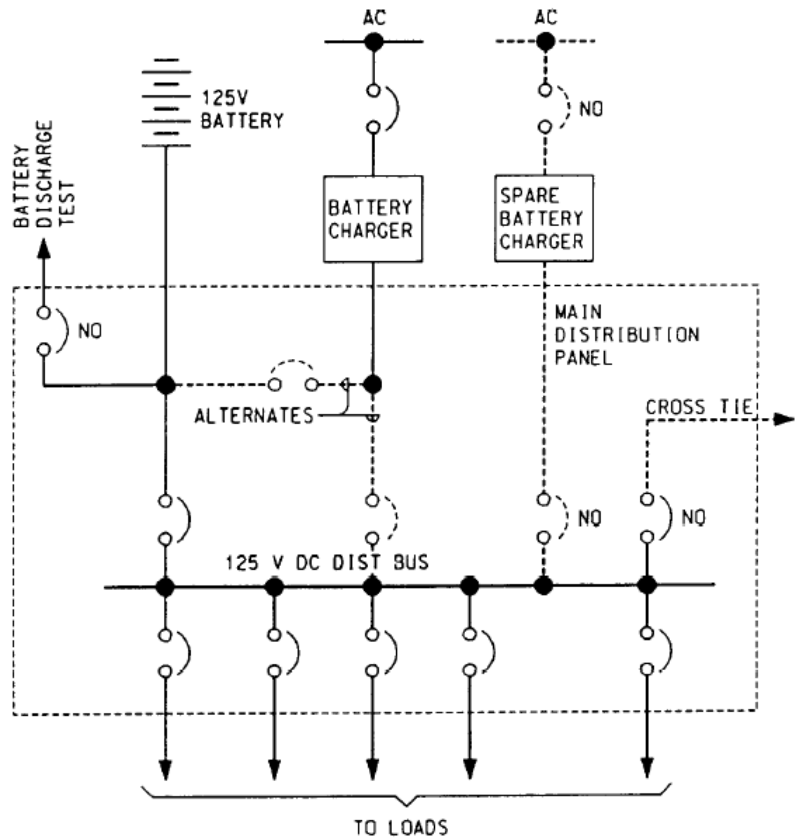
C. Determine system loads and duty cycles for the postulated events. Size battery in accordance with IEEE Std 485 or IEEE Std 1189 (depending on the battery type) using the following factors:

1. Temperature correction factor 1.0
2. Design margin factor 1.0
3. Aging factor 1.25

D. Provide battery power system with 20 percent future load growth capacity.

E. Certain critical loads such as Safety Class systems or critical telecommunications loads may require increased system reliability beyond that which can be provided by a single UPS system. Determine reliability requirements and system capabilities using analysis methods described in IEEE Std 493.[72] Provide redundant battery chargers and/or cross ties to redundant battery systems as required to meet availability and reliability requirements needed to meet User requirements. Refer to Figure D5090-4 for a 125v battery system that is typical for substation switchgear control applications; other applications will have different voltages, components and configurations.

Figure D5090-4: Typical Switchgear Control Battery System



F. Provide means to safely and conveniently connect a load bank to the battery system for capacity tests. Refer to Figure D5090-4.

G. Provide battery power system with instruments or other approved display means, including remote annunciation capability, to indicate the following:[73]

1. Battery current (ammeter, charge or discharge).
2. Battery charger output current (ammeter).
3. Battery or DC bus voltage (voltmeter).
4. Battery charger output voltage (voltmeter).

H. Provide individual visual indicators, a common audible annunciator, and contacts for remote alarm annunciation for the following: [73]

1. Low battery voltage.
2. High battery voltage.
3. Battery circuit breaker open.
4. Battery charger output failure.
5. High pilot cell temperature.
6. High battery current.

I. Provide a DC ground fault detection & alarm system for battery strings with nominal voltage of 125 volts or more.[74]

J. Provide a battery integrity monitoring system that operates on a battery interconnection point basis for the following systems: [57]

1. System serving load over 225 kVA.
2. System with battery replacement cost over $20,000.
3. System serving Safety Class systems.

K. Provide "battery-eliminator" type battery charging equipment that meets NEMA PE5—*Utility Type Battery Chargers* and is listed to UL 1012.[75]

L. Provide DC distribution system with components suitable for the maximum value of charger short circuit current that will occur coincident with the maximum battery short circuit current.[76]

M. Select DC system overcurrent devices to provide selective coordination.[77]

4.4 Installation

A. Design battery installation in accordance with IEEE Std 484, IEEE Std 1106, or IEEE Std 1187 (depending on the battery type) and the considerations described below.

B. Locate the battery power system equipment as close together and as near the center of the load as practical to minimize voltage drop and to accommodate maintenance and testing activities.[78]

C. Locate batteries within a protective enclosure or area accessible to qualified persons. A protective enclosure can be any of the following that will adequately protect the battery power system equipment, limit the likelihood of inadvertent contact with energized parts, and limit damage to adjacent equipment from battery fumes or spray:[79]

1. A dedicated battery room.
2. An approved battery cabinet.
3. A suitable cage or a fenced area.

D. Provide working spaces around battery power system equipment as required by the NEC.[80]

E. Locate battery power system components considering floor loading, installation and replacement access, maintenance access, and the following guidance:[81]

1. *For a system serving over 15 kVA load, provide a battery or cabinet with batteries on slide-out trays.*
2. *For a system serving over 100 kVA load, battery should be rack mounted in dedicated battery room; provide minimum 4 ft aisles between racks.*
3. *Battery serving Safety Class loads should be rack mounted in a dedicated battery room rated for design basis event.*
4. *Limit height of battery racks so top terminal of battery is not more than 53 inches above floor. Provide minimum 15 inches vertical clearance above battery.*

5. *Use extra flexible cable for external connections to battery terminals. Allow for 6 inches of battery rack movement during an earthquake.*

F. Provide Class C portable fire extinguisher(s) in the battery room.[82] Coordinate size and placement with the LANL Fire Protection Group.

G. Install an emergency eyewash/shower station in each battery room or within 25 feet of a rack-mounted battery.[83]

H. Provide battery area HVAC system considering operating temperature, adequate ventilation, and the following requirements: [84]

1. Maintain yearly average temperature at 77 ºF, 60 ºF to 80 ºF maximum range.
2. Provide 30 percent efficiency air filtration.
3. Temperature must not vary more than 5 ºF from coolest to warmest parts of room at any time.
4. Provide sufficient ventilation (not less than 2 air-changes per hour) to keep hydrogen concentration below 1 percent when battery is on equalizing charge; independently vent battery room exhaust to outside. *A battery room that meets the above ventilation requirements should be considered as non-hazardous; thus special electrical equipment enclosures to prevent fir or explosions should not be necessary.*[85]

I. Provide battery rooms for vented (flooded) cell batteries with appropriate additional systems such as:

1. *Acid absorption pads or pans to contain acid from a ruptured cell.*
2. *Acid resisting construction.*
3. *Hydrogen monitoring system.*
4. *Battery room sink with acid neutralizing basin.*
5. *Annunciation of ventilation system failure at a monitored location.*
6. *Spill control kit.*

J. Provide adequate illumination for the battery area[86]; refer to section D5020 of the LEM.

1. Protect luminaires from damage by guards, finishes, or isolation.
2. Locate lighting switches and receptacles outside the battery area.
3. Provide emergency illumination for the battery location.

K. Provide safety signs inside and outside the battery room or in the vicinity of a battery area prohibiting smoking, sparks, or flame. Refer to section D5000 of the LEM for information regarding safety signs.[87]

4.5 Battery System Acceptance Testing and Inspection

A. Perform complete acceptance testing and inspection of completed battery power system systems in accordance with NFPA 111[88] and IEEE Std 450.[89]

1. Provide advance notification of acceptance testing to the LANL Electrical AHJ.

2. Tests shall be performed by qualified personnel such as the battery manufacturer's factory-trained technicians or technicians that are certified in accordance with ANSI/NETA ETT-2000, *Standard for Certification of Electrical Testing Technicians*.
3. Make a detailed record of acceptance test results on a form suitable for the purpose.
4. Provide analysis and recommendations with the acceptance test report.

B. Provide copies of the acceptance test report and all certifications to the LANL electrical AHJ and to the Facility Manager. Acceptance tests will provide baseline data for the LANL battery maintenance program.

5.0 CABLE TRAY SYSTEMS

5.1 Cable Tray Selection

A. Provide cable tray and accessories manufactured in accordance with the latest edition of NEMA VE1–*Metal Cable Tray Systems* or FG1–*Fiberglass Cable Tray Systems*.[90]

B. Use cable tray type suitable for the supported cables.[91]

1. *Ladder-Type Cable Tray consists of two longitudinal side rails (or the structural equivalent) connected by individual cross members or rungs. Use for large power, control, and communications cables.*
2. *Ventilated Trough-Type Cable Tray consists of two side rails (or the structural equivalent) with closely spaced supports. Use for small power, control, and communications cables.*
3. *Solid Bottom Cable Tray consists of two side rails (or the structural equivalent) connected with a corrugated or reinforced solid bottom. Use for power, control, and communications cables requiring maximum electrical or magnetic shielding.*

C. Provide cable trays that have suitable strength and rigidity to provide adequate support for all contained wiring plus a 200 lb. concentrated load at mid-span.[92] For cable trays installed outdoors, add loading due to snow, ice, and wind. *The following are guidelines to suitable minimum working load categories for cable trays:*

1. *6 and 12 in. widths: 50 lbs. per linear foot plus a 200 lb. concentrated load at mid-span.*
2. *18 and 24 in. widths: 75 lbs. per linear foot plus a 200 lb. concentrated load at mid-span.*
3. *30 and 36 in. widths: 100 lbs. per linear foot plus a 200 lb. concentrated load at mid-span.*

D. Use cable trays made of corrosion-resistant material or adequately protected from corrosion that may be encountered in use; refer to manufacturer's corrosion resistance data. *Some of the commonly available materials and finishes are listed below in approximate order of increasing installed costs:*[93]

1. *Aluminum alloy 6063-T6. Use for most outdoor or indoor applications.*
2. *Carbon steel mill galvanized. Use for non-corrosive indoor applications.*
3. *Carbon steel hot dip galvanized AFTER fabrication per ASTM A123. Use for non-chemical outdoor and industrial indoor applications.*
4. *Aluminum or steel coated with 15 mils of PVC. Use in chemical environments.*

5. *Stainless steel type 304. Use in severe chemical environments.*
6. *Stainless steel type 316. Use in severe chemical environments.*
7. *Fiberglass with polyester fire-retardant resin system type FR-P. Use where electrical isolation is required or in severe chemical environments.*
8. *Fiberglass with vinyl ester fire-retardant resin type FR-VE. Use in severe chemical environments.*

5.2 Cable Tray Installation

A. Install cable tray in accordance with the NEC, NEMA VE-2 – "Metal Cable Tray Installation Guidelines", and this Engineering Manual.[94] Refer to Section D5000 of the LEM for additional requirements for nuclear facilities.

B. Verify that the building structure has adequate capacity to support the fully loaded cable tray(s) with a factor of safety of 4 (based on material yield strength).[95]

C. Support cable trays with wall/column brackets or with threaded rods suspended from beam clamps or concrete inserts. Select beam clamps, concrete anchors, fasteners, and support rods based on the weight of the cable tray loaded to maximum cable capacity permitted by the NEC plus a 200 lb concentrated load at mid-span plus applicable snow, ice, and wind loads.

D. Provide longitudinal and transverse seismic bracing. For cable trays in DOE-STD-1020 PC-1 or PC-2 service refer to Cable Tray Seismic Bracing, Figure D5090-5. Consult a qualified structural engineer for the appropriate seismic bracing of cable trays carrying life safety systems, safety class systems, or for cable trays installed in PC-3 or PC-4 facilities.

E. In stacked tray installations, separate voltages; locate the lowest voltage cables in the bottom tray and succeeding higher voltage cables in ascending order of trays.[96]

F. Provide and maintain sufficient space above and beside cable trays to permit access for installing and maintaining cables.[97]

   1. Locate cable trays not less than 12 inches below building structure, suspended mechanical equipment, piping, ductwork, and other cable trays that would impede access to the cable tray(s).
   2. *Consider center hung tray supports or bracket supports to improve access to the tray for installing cables.*

G. Do not drill or punch holes in side channels of suspended cable tray other than those for splice plate bolts or grounding conductor connection fittings. *Conduits may be terminated into the side channels of continuously supported cable trays.*[98]

H. Provide covers as required to protect cables from deteriorating agents.[99]

   1. Provide covers for cable trays installed outdoors.[100]
   2. Provide covers for cable trays installed indoors that contain power cables where that pass under pipes containing liquids; extend covers 6 feet on each side of crossing location.

5.3 Cable Tray Grounding

A. Install an equipment grounding conductor in cable trays sized per the NEC[101] but not smaller than #6 copper. [102] Use insulated copper equipment grounding conductors in aluminum cable trays.[103]

B. Bond the equipment grounding conductor to each cable tray straight section and fitting using UL listed cable tray ground clamps.[104]

C. Bond the equipment grounding conductor to each enclosure or equipment item connected to, or served by, the cable tray using UL listed ground clamps.[105]

D. Install splice plates in accordance with cable tray manufacturer's instructions.

E. Bond raceways served from cable tray using UL approved conduit clamps or grounding bushings. [105]

5.4 Cable Installation

A. Use cable that is approved for installation in cable tray and is approved for the location and conditions.[106]

B. Make original installations of cables in cable trays without splices.[107] *Existing cables in cable trays may be repaired using UL approved splice kits or materials.*

C. Make original installations of cables in cable trays to permit future 20 percent future additions of cable.[108]

D. Install drop-out fittings or bushings to provide a rounded surface to protect cables exiting from the bottom of cable trays.[109]

E. Do not install pipes or tubes for water, steam, gas, drainage, or any service other than electrical in cable trays containing electric conductors or raceways.[110]

5.5 Cable Tray Labeling

A. Install yellow warning labels with 1/2 inch black letters and the following message at visible locations 50 feet on centers on all cable trays:[111]

WARNING: DO NOT USE CABLE TRAY AS A WALKWAY, LADDER, OR SUPPORT. USE ONLY AS MECHANICAL SUPPORT FOR CABLES OR TUBING.

B. Install red warning labels with 1/2 inch white letters and the following message at visible locations 50 feet on centers on all cable trays in environmental or return air plenums:[112]

USE ONLY PLENUM RATED CABLES IN THIS CABLE TRAY.

C. Install white labels with 1/2 inch black letters and the following information at visible locations 50 feet on centers on all cable trays:

1. Maximum cable tray loading depth.

2. Allowable cable load in pounds per foot based on the as-installed support span and spacing and structural support capability.

Figure D5090-5
CABLE TRAY SEISMIC BRACING

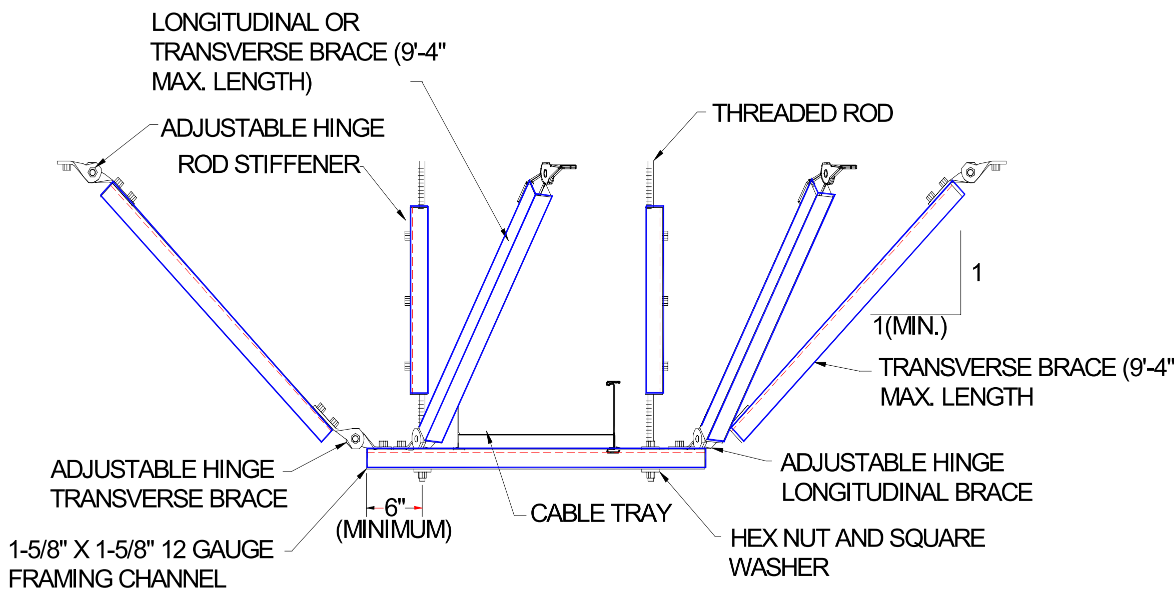


Table D5090-2
Cable Tray Trapeze Support and Seismic Bracing
(For PC-1 and PC-2 Service)

NEMA Class of Cable Tray[113]	Load on Each Trapeze Hanger Rod (lb)[114]	Minimum Trapeze Hanger Rod Size (inches)[115]	Max. Rod Length Without Stiffener (inches)	Concrete Structure[116]		Steel Structure[117]	
				Maximum Sway Brace Spacing (ft)[118]	Minimum Brace Anchor Strength (lb)[119]	Maximum Sway Brace Spacing (ft)	Minimum Brace Anchor Strength (lb)
8A	400.0	3/8"	19	40	500	40	500
8B	533.3	3/8"	19	32	600	40	750
8C	666.7	1/2"	25	24	600	40	1000
12A	533.3	3/8"	25	36	450	36	450
12B	733.3	1/2"	25	36	675	36	675
12C	933.3	1/2"	25	24	600	36	900
16A	666.7	1/2"	25	32	400	32	400
16B	933.3	1/2"	25	32	600	32	600
16C	1200.0	5/8"	31	32	800	32	800
20A	800.0	1/2"	25	40	500	40	500
20B	1133.3	5/8"	31	40	750	40	750
20C	1466.7	5/8"	31	20	500	40	1000

6.0 SIGNAL REFERENCE GRID

A. Install a signal reference grid (SRG) for computer room raised floor areas. *Refer to IEEE Std. 1100–Powering and Grounding Electrical Equipment for additional design guidance.*

B. Use one or a combination of the following systems:

1. Pre-fabricated grid of 2 inches wide by 26 gauge copper strips on 2-foot centers with all crossover connections factory welded. Bond every sixth raised floor pedestal to the SRG using No. 6 AWG grounding conductor.
2. Raised floor pedestal system with bolted down galvanized steel horizontal stringers.
3. 2 ft X 2 ft grid of bare No. 6 AWG conductors clamped to raised floor pedestals.

C. Bond structural steel columns, pipes, conduits, ducts, etc. passing through the SRG to the SRG using No. 6 AWG grounding conductor.

D. Bond computer equipment, power panels, and computer distribution units to the SRG using low impedance risers (LIR).

1. Install LIR as 2 inches wide, 26 gauge copper strips or 1 inch wide flexible braided copper straps.
2. Do not connect the LIR to the SRG conductor closest to the outside edge of the SRG.
3. Keep the LIR as short as possible.
4. If LIR exceeds 24 inches, install two parallel LIRs connected to opposite corners of the equipment. Make the second LIR 20 percent to 40 percent longer than the first.

7.0 LIGHTNING PROTECTION SYSTEMS

7.1 Criteria

A. Provide a lightning protection system (LPS), including surge protection equipment, for each structure that meets any of the following criteria:[120]

1. Contains facilities for the use, processing, and storage of radioactive, explosive, and similarly hazardous materials.[121]
2. Extends more than 50 feet above adjacent structures or terrain.[122]
3. Contains equipment valued over $1 million, critical operating equipment or services considered essential to public safety.[123]
4. Is protected by an automatic sprinkler system.[124]
5. A lightning risk assessment as described in Appendix H of NFPA 780 indicates that the calculated “expected lightning stroke frequency to the structure” (N_d) is greater than the calculated “tolerable lightning frequency to the structure” (N_c).[125]

B. For the lightning risk assessment described in Appendix H of NFPA 780 use a flash density of 8 flashes/km^2/year for all LANL facilities.[126]

C. For structures not used for the storage or handling of explosives, design and install the LPS in accordance with:

1. NFPA 780–*Standard for the Installation of Lightning Protection Systems,*[127] supplemented by UL 96A–*Installation Requirements for Lightning Protection Systems*, and LPI 175–*LPI Standard of Practice*.
2. LANL Construction Specifications Section 16670–*Lightning Protection*,
3. And this section of the LANL Engineering Manual.

D. For structures used for the storage or handling of explosives, meet the requirements of DOE M 440.1-1–*Explosives Safety Manual*.

1. Design and install the LPS for explosives handling and storage facilities according to the requirements described above plus:
   - NFPA 780 Appendix K[128]
   - MIL-HDBK 1004/6–*Lightning Protection*,[129]
2. The acceptable types of LPSs are mast, catenary, integral air terminal, and Faraday cage or Faraday-like shield systems. Faraday cage or Faraday-like shield systems (in conjunction with a Franklin-type system to protect the structure) are preferred for new explosives handling and storage facilities.[130] *The Faraday cage is intended to protect the interior of the structure and its contents from high electric fields and resultant arcs; the Franklin type system (NFPA 780 mast, catenary, and integral air terminal systems) is intended to protect the structure from fire, perforation, and other damage.*
3. Bring existing explosives handling and storage facilities into compliance with the above requirements by May 7, 2008.[131]

E. Extend an existing LPS to any building addition if the addition is not within the existing LPS "zone of protection". Determine the "zone of protection" using the "rolling sphere" concept described in NFPA 780.[132]

1. For structures not used for the storage or handling of explosives use a rolling sphere with a radius of 150 ft.
2. For structures used for the storage or handling of explosives use a rolling sphere with a radius of 100 ft.[133]

F. For new installations or major renovations, require that the installer furnish shop drawings showing LPS, installation details, and list of materials.

G. Use a qualified installer to design and install the LPS. Installer must have either a current LPI Master Installer certification or current UL listing (Category OWAY) for Lightning Protection Installation.[134]

7.2 Grounding System

A. For new structures install an LPS ground ring electrode (counterpoise), minimum 1/0 AWG[135] (4/0 AWG[136] for Class II systems) bare copper, at a distance of five feet from the foundation and 3 feet below grade[137]. Locate at least 6 feet from any electrical system or communications system ground electrode.[138] Backfill with a non-corrosive ground enhancement material to lower resistance to earth.[139] Design grounding electrode system to obtain the following ground resistance:

1. Structures <u>not</u> used for the storage or handling of explosives: 25 ohms or less
2. Explosives handling and storage facilities: 10 ohms or less.[140]

B. For existing structures verify the integrity and measure the ground resistance of the existing LPS grounding electrode.

1. Verify that the LPS grounding electrode is a separate electrode from that used for the building electrical system.
2. Install supplemental grounding electrodes to obtain an LPS ground resistance of 25 ohms or less for ordinary structures and 10 ohms for or less for explosives handling and storage facilities. *Electrolytic ground rods installed in accordance with the manufacturer's instructions may be used for such supplemental electrodes.*

C. Bond the LPS counterpoise to the main building grounding electrode bar at the service entrance.[141]

7.3 Materials

A. Use LPS materials that are NRTL listed to UL 96–*Standard for Safety for Lightning Protection Components.*

B. Use copper or bronze LPS materials.[142] Aluminum may be used only if LPS material is to be installed in contact with surfaces made of aluminum.

C. Use rope lay main and bonding conductors.[143]

D. Use bolted pressure type connectors; finger style crimp connectors are not acceptable.[144]

E. For new LPSs, use air terminals with blunt tips.[145]

7.4 Installation

A. For new construction use a maximum air terminal spacing of 20 feet around the perimeter of the roof.[146] *Avoid long air terminals that overturn adhesive bases or require supplemental supports.*

B. To the maximum extent possible, install roof conductors so they will be visible for inspection and testing.

C. Install down conductors either concealed or exposed as permitted by NFPA 780.

1. *Avoid the use of through-roof connectors; make connections in parapet walls where possible.*

2. To facilitate verification of connections to the LPS ground, install an accessible down conductor disconnect in each down conductor except the one nearest the electrical service entrance. Disconnects for concealed down conductors may be installed behind access panels or cover plates.

D. Bond metallic piping systems (water, gas, sewer, etc) entering the building to the LPS.[147]

E. Use the following LPS connection methods unless otherwise required by this section or applicable codes:

1. Exothermic weld connections for underground or concealed connections of dissimilar materials.
2. Exothermic weld or IEEE Std. 837 compression connectors for underground or concealed connections of like materials. Do not use compression connections for rope lay lightning conductor connections or for ground rod connections.
3. Exothermic weld or bolted connections for accessible connections.

F. Do not paint LPS bonds or connections.[148]

7.5 Surge Protection

A. Provide surge protection for electrical circuits entering and exiting all structures, including structures that may not have LPS on the roof.

B. Provide an NRTL listed surge protection device (SPD) for each electrical service entering the structure.[149] Use SPDs that are listed per UL 1449 and are suitable for Location Category C3 as defined in IEEE Std. C62.41.[150] Refer section D5010 of the LEM for service entrance SPD performance requirements.

C. Provide an NRTL listed SPD for each electrical feeder, branch circuit, and control circuit extending from the structure to locations having exposure to lightning.[151] *Examples include circuits to other structures, to parking lot lighting, and to outside HVAC equipment.* Use SPDs that are listed per UL 1449 and are suitable for the application environments as defined in IEEE Std. C62.41. Use the same kind of SPDs as required for electrical services in section D5010 of the LEM.

D. Provide an NRTL listed SPD device for each fire alarm, security, and similar low-voltage circuit extending from the structure to other structures. Use SPDs that are listed per UL 497 and UL 497A and are suitable for the application environments.[152]

E. Provide an SPD for each antenna cable or CCTV camera cable that enters the structure.[153] Where several such cables enter at one location, provide an enclosure with ground connection provisions for the SPDs.

F. Verify that suitable SPDs have or will be installed on each telecommunications line that enters the structure.

G. All electrical power circuits, communications circuits, shielded cables, etc. must be run underground in metal conduit for a minimum of 50 feet before they enter an explosives handling and storage facility. SPDs for power circuits, communications circuits, shielded cables, etc. must be installed at the transition to underground conduit, outside the 50-ft limit.

7.6 Acceptance Inspection

Acceptance inspection of the LPS will be by the LANL lightning protection subject matter expert (SME). Correct all deficiencies promptly.

ENDNOTES:

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1 The Electrical Generating Systems Association (EGSA) is a trade association made up of nearly 600 companies in the USA and around the world that make, sell, distribute, specify, service, and use on-site power equipment. The organization develops performance standards for on-site power technology.

2 Based on daily extremes for White Rock: http://weather.lanl.gov/html/WRExtremes.html

3 Voltage dip is based on the 25% drop out voltage for NEMA AC control relays.

4 Type is maximum time (in seconds) that the load is permitted to be without acceptable power. Refer to NFPA 101-2002 paragraph 4.3 and Table 4.1(b).

5 Class is the minimum hours of operation at full load without being refueled. Refer to NFPA 110-2002 paragraph 4.2 and Table 4.1(a).

6 Level indicates the stringency of requirements for installation, performance, and maintenance. Level is assigned to the various kinds of loads on a graded approach based on consequence of failure. Refer to NFPA 101-2002 paragraph 4.4.

7 Refer to NFPA 110-2002 paragraph 5.1.2. Required 96 hours on-site fuel supply for Level I systems is due to remoteness of LANL and the possibility of seismic activity

8 DOE M5632.1C-1 requires not less than 8 hours of standby capability power for security systems. This requirement is expanded to 48 hours due to the remoteness of LANL. Telecommunications systems are considered to be an integral part of "defense in depth" security systems and are important to public safety.

9 Refer to NFPA 110-2002 paragraph 5.1.

10 On-site fuel supply is required because the probability of interruption of off-site fuel supply is considered high due to remoteness of LANL and the possibility of seismic activity.

11 Refer to NFPA 110-2002 chapter 6.

12 A bypass-isolation transfer switch permits safe maintenance of the transfer switch while keeping critical systems in operation: refer to 4.3.10 in IEEE Std 446-1995.

13 Refer to A.6.2.5 in NFPA 110-2002.

14 Refer to A.6.2.8 in NFPA 110-2002.

15 Refer to A.6.2.13 in NFPA 110-2002.

16 In-phase transfer systems permit motors to continue to run with little disturbance to the electrical system and processes during re-transfer operation; refer to 4.3.8 in IEEE Std 446-1995.

17 Engine-generator systems usually have a factory-made connection from the generator neutral to the frame of the machine. The purpose of the 4-pole transfer switch is compliance with 2002 NEC section 250.42(A)(5) which prohibits load side grounding connections to the grounded (neutral) conductor.

18 Refer to Chapter 6 in IEEE Std 446-1995.

19 The hazardous waste issues associated with nickel-cadmium batteries preclude their use; refer to 5.3.2 in IEEE Std 446-1995.

20 Valve-regulated lead-acid batteries are considered less reliable than vented-cell lead acid batteries. NFPA 110-2001 prohibits the use of valve-regulated lead-acid batteries for Class I systems. This prohibition is extended to Class II systems by the LEM.

21 Refer to 5.3.3 and 5.3.4 in NFPA 110-2002.

22 Refer to 5.6.5.2(4) in NFPA 110-2002.

23 Refer to 5.6.6 in NFPA 110-2002.

24 The radiator fan is a significant source of engine-generator set noise.

25 Generator sets approximately 150 kW and smaller can be enclosed in commercially available weather-protective sound attenuating housings that reduce noise to less than 70 dBA measured 7 meters away. Barriers can be installed around housings for larger generator sets to reduce noise.

26 Refer to 7.11.6 in NFPA 110-2002. NFPA 110 requirement for UBC seismic zones 3 and 4 extended to LANL, which is in seismic zone 2B.

27 Recommendations in A7.11.5 in NFPA 110-2001 made requirements at LANL.

28 Refer to 8.4 in NFPA 110-2002. The EGS must be exercised at least monthly under not less than 30% nameplate kW load. If the facility load connected to the EGS does not meet this requirement, or is not available for operational reasons, a supplemental load bank must be provided. It is not practical to use portable load banks for the monthly exercising of all the EGSs at LANL.

29 Refer to 8.4.2 in NFPA 110-2002.

30 Refer to 445.18 in the 2002 NEC.

31 Refer to 445.12 in the 2002 NEC.

32 Refer to 700.7(D) in the 2002 NEC.

33 Refer to 445.13 in the 2002 NEC.

34 Refer to Chapter 7 in IEEE Std 446-1995 for an in-depth discussion of the pros and cons of grounding the neutral at the generator and using 4-pole transfer switches. Problems associated with multiple transfer switches, ground fault protection of the emergency system, and potential hazardous conditions during certain maintenance operations are largely eliminated through grounding the neutral at the generator and using 4-pole transfer switches.

35 Refer to 7.13 in NFPA 110-2002.

36 Refer to 7.13.3 in NFPA 110-2002.

37 A UPS system with true online double conversion provides complete isolation from problems originating from utility or generator power. Other UPS topologies may have lower initial costs, they may not provide protection against all power problems including power system short circuits, frequency variations, harmonics, and common-mode noise. Refer to paragraph 5.5.3.1 in IEEE Std 446-1995.

38 Refer to 5.4.2 in IEEE Std 944-1986 and 7.3.1.1 in IEEE Std 1100-1999.

39 Refer to Article 220 in the 2002 NEC.

40 Refer to 2.2.2 in NFPA 111-2001. Type 0 characterizes UPS system with online double conversion.

41 Refer to 2.2.3 in NFPA 111-2001. Class is the minimum time, in hours, for which the UPS is designed to operate at rated load without being recharged. Class is assigned to the various kinds of loads on a graded approach based on consequence of failure. When generator backup is available, the Class is reduced to a credible maximum time for the generator to be started based on a graded approach based on consequence of failure.

42 Refer to 2.2.5 in NFPA 111-2001. Level indicates the stringency of requirements for installation, performance, and maintenance. Level is assigned to the various kinds of loads on a graded approach based on consequence of failure.

43 DOE M5632.1C-1 requires not less than 8 hours of standby capability power for security systems.

44 Refer to Figure 3 in IEEE Std. 308-1991.

45 Emergency response time is the total time it takes for a service provider to arrive on the job site after an emergency service request has been placed. Response time is based on Level using a graded approach based on consequence of failure.

46 Refer to paragraph 5.4.5 in NFPA 111-2001.

47 Recommendations in A.5.4.5 in NFPA 111-2001 made requirements at LANL.

48 Refer to paragraph 5.2.2 in NFPA 111-2001

49 Addition of a bypass switch makes the UPS system 8 – 10 times more reliable. Refer to paragraph 5.5.4.3 in IEEE Std 446-1995.

50 Based on capabilities of commercially available products.

51 Requirement that cabinet be completely de-energized for maintenance aligns with requirements in paragraph 7.4.3 of LIR402-600-01, *Electrical Safety* and LIR402-860.01, *Lockout/Tagout for Personal Safety*.

52 A separate bypass input source increases UPS system reliability and makes it possible to maintain the UPS and upstream circuit breakers while still providing power to critical loads.

53 Refer to Chapter 6 in IEEE Std 493-1997.

54 If the primary UPS module should fail, the secondary UPS module will continue to provide conditioned power to the critical load through the static switch in the Primary UPS module. The circuit breakers in the bypass switchgear can be arranged so either UPS module can support the critical load while maintenance or repairs are being performed on the other. Refer to section 7.3.2.1.2 in IEEE Std 1100-1999.

55 Either UPS system can support the critical load while maintenance or repairs are being performed on the other.

56 Since the battery is the most failure-prone sub-system of the UPS, monitoring battery condition is essential to UPS system reliability.

57 Battery monitoring improves system reliability by detecting battery problems at an early stage, before they can cause an abrupt system failure. Problems are detected by measuring the internal resistance of each cell or module in the system. The internal resistance of a cell is a reliable indicator of a battery's state of health. The only other method for testing a battery's condition is to perform a capacity test, but users are often reluctant to capacity tests their battery systems. With a suitable battery monitoring system a resistance test can be performed automatically by remote control.

58 Refer to section 645.11 in the 2002 NEC.

59 Refer to Chapter 10 in IEEE Std 519, *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*. Current total harmonic distortion (THD) at the service point is limited to 5%. It is anticipated that approximately half of the loads in a facility will be harmonic producing. Therefore significant individual harmonic producing loads, such as UPS, are limited to 10% current THD.

60 Refer to Chapter 5 in NFPA 111-2001.

61 Refer to Chapter 5 in IEEE Std 484-1996 for vented lead-acid batteries and Chapter 5 in IEEE Std 1187 for valve-regulated lead-acid batteries.

62 100F is the maximum ambient temperature listed by most UPS manufacturers. 50F is the minimum ambient temperature in which a UPS service technician can work efficiently.

63 30% filtration will provide adequate cleanliness in the UPS space. Refer to LEM Chapter 6.

64 If UPS room HVAC stops when the UPS is operating on battery power, the UPS space temperature will quickly rise and the UPS will shut down due to overtemperature.

65 If UPS room HVAC is shut down for maintenance, the UPS space temperature will quickly rise and the UPS will shut down due to overtemperature.

66 Non-linear UPS load imposes unusual conditions on high-impedance sources such as engine-generator systems.

67 Emergency lighting will facilitate troubleshooting the UPS during a power blackout.

68 Refer to 5.4.4 in NFPA 111-2001 and 8.6.5 in IEEE Std 1100-1999.

69 Refer to 5.6 in NFPA 111-2001.

70 Refer to Chapter 7 in IEEE Std 944-1986.

71 Refer to 7.5 in IEEE Std 1100-1999.

72 Refer to Chapter 6 in IEEE Std 493-1997.

73 Refer to Table 2 in IEEE Std 946-1992.

74 DC distribution systems are typically two-wire ungrounded battery/charger systems equipped with ground-detection/alarm circuitry including features such as annunciation in a control room, local indication, and recording. Ground detectors are incorporated in the DC systems so that if a single ground does occur, personnel are aware of the ground and can take immediate steps to clear the ground fault from the system. Failure to promptly eliminate a single ground could mask subsequent additional grounds. Multiple grounds could lead to unpredictable spurious operation of equipment, inoperable equipment, unanalyzed loads on batteries, or unanalyzed equipment failure modes that could be expected to occur during harsh environments attendant to accidents. In addition, installed ground detectors and portable ground-locating equipment themselves may create a ground on the dc system and may not maintain a minimum threshold resistance-to-ground value above which predictable system/component operation can be assured.

75 A "battery-eliminator" type charger will allow the charger to support the DC load while the battery is disconnected for repairs, maintenance, or testing.

76 Refer to 7.9 in IEEE Std 946-1992 and 4.5.1 in NFPA 111-2001.

77 Refer to 4.5.2 in NFPA 111-2001.

78 Refer to 4.5 in IEEE Std 946-1992.

79 Refer to 2002 NESC rule 141.

80 Refer to 2002 NEC article 110.26. This NEC requirement is repeated here to remind designers that working the NEC working clearances are required about batteries.

81 Refer to 5.2 in NFPA 111-2002.

82 Refer to 4.1 in IEEE Std 484-1996.

83 Refer to OSHA 1926.441(a)(6).

84 Refer to 5.1 on IEEE Std 484-1996.

85 Refer to 5.4 in IEEE Std 484-1996.

86 Refer to 2002 NESC rule 145.

87 Refer to 2002 NESC rule 146.B.

88 Refer to 5.6 in NFPA 111-2001.

89 Refer to Chapters 5 and 6 in IEEE Std 450-1995.

90 NEMA VE1 and FG1 are the industry standards for metal and fiberglass cable tray.

91 Descriptions of cable tray types are from NEMA VE1. Recommended uses are from manufacturer’s data.

92 Although walking or standing on cable trays is not recommended by cable tray manufacturers and OHSA regulations, it happens.

93 Corrosion resistance criteria are from manufacturer’s literature.

94 NEMA VE-2 is a practical guide for the proper installation of steel and aluminum cable trays.

95 Factor of safety is to allow for stresses during installation of cables, stresses during seismic events, and uncertainties about the building structure.

96 Table tray stacking recommended practice is in section 12.5.5 in IEEE Std. 141.

97 Requirement from 2002 NEC section 392.6(I) is repeated for emphasis.

98 Randomly placed holes in the side channels will reduce the beam strength of a cable tray. This is not an issue if the cable tray is continuously supported, such as on the structural floor below a raised floor system.

99 Refer to section 392.6(C) in the 2002 NEC.

100 Ultraviolet light is an outdoor deteriorating agent.

101 Refer to Table 250.122 in the 2002 NEC.

102 IEEE 1100, paragraph 8.4.12, recommends that a supplemental equipment grounding conductor be used, even if the cable tray qualifies for use as an equipment grounding conductor.

103 Refer to 4.7.2 in NEMA VE 2.

104 Refer to section D5000, which requires the use of listed fittings.

105 Bonding of cable tray to enclosures and raceways enhances personnel safety by eliminating “touch potential”; refer to 2002 NEC Article 250.96.

106 Refer to section D5000, which requires the use of listed materials in accordance with their listing.

107 Splices should be avoided in any new installation because they are a point of reduced reliability.

108 Planning for future growth of cable tray use is recommended practice in section 12.5.5 in IEEE Std. 141-1993 and is consistent with Section D5000 of the LEM.

109 Refer to NEMA VE2, Metal Cable Tray Installation Guidelines, paragraph 4.6.2, for cable tray drop out fittings.

110 This requirement from 2002 NEC section 300.8 is repeated here for emphasis.

111 Cable tray warning label recommended in paragraph 6.3 of NEMA VE 1.

112 2002 NEC Article 300.22(C) specifically limits the types of wiring methods that may be used within “other spaces used for environmental air.”

113 Cable tray loading = NEMA Class loading (50, 75, or 100 lb./ft) X span (8, 12,16, or 20 ft) + 200 lb. at mid span.

114 Each trapeze hanger rod is selected to carry 2/3 of the load on the trapeze.

115 Threaded rod allowable loads: 3/8" = 610 lb., 1/2" = 1130 lb., 5/8" = 1810 lb.

116 For concrete structure, 3000 psi concrete is assumed. Assumed maximum practical connector uses two 1/2" carbon steel expansion anchors.

117 For steel structure, connection strength = 1130 lb.

118 Maximum sway brace spacing is 40 ft; this is further limited by the brace-to-structure connection strength.

119 Force on sway brace connection = 0.25 X weight between braces.

120 Criteria from DOE-STD-1066-99, Fire Protection Design Criteria.

121 DOE G 420.1-1 requires that lighting protection be considered for buildings and structures that contain, process, and store radioactive, explosive, and similarly hazardous materials.

122 NFPA 780 risk index increases significantly for tall structures.

123 NFPA 780 risk index increases significantly for structures having high-value contents, critical operating equipment, or essential services.

124 The logic is that a facility that warrants an automatic sprinkler system also warrants lightning protection.

125 Refer to Appendix H in NFPA 780, 2000 Edition.

126 Based on flash density map from Global Atmospherics that covers a 30-mile radius centered on LANL TA-3.

127 NFPA 780 is included in the set of LANL "Work Smart Standards".

128 Appendix K to NFPA 780 is elevated to a requirement document for explosives processing and storage facilities at LANL.

129 MIL-HDBK 1004/6 addresses the design of lightning protection for explosives facilities much more comprehensively than NFPA 780.

130 Refer to §2.0c in Version 11C "IMPROVEMENTS TO THE DOE EXPLOSIVES SAFETY MANUAL" dated 4/18/02, voted and approved at the 46th DOE Explosives Safety Committee Meeting, 5/07/02.

131 Refer to §1.0 in Version 11C "IMPROVEMENTS TO THE DOE EXPLOSIVES SAFETY MANUAL" dated 4/18/02, voted and approved at the 46th DOE Explosives Safety Committee Meeting, 5/07/02.

132 Refer to §3.7.3 in NFPA 780, 2000 Edition.

133 Refer to §6.3.3.1 in NFPA 780, 2000 Edition.

134 Installer certification or listing assures national standards are met including those set forth in NFPA 780 and UL 96A. Certification places requirements on design, materials, workmanship, and inspection.

135 1/0 AWG is a close match to the outside diameter of the main conductor for Class I systems.

136 4/0 AWG is a close match to the outside diameter of the main conductor for Class II systems.

137 Ground ring should be located below the frost line, generally accepted as 36 inches in Los Alamos.

138 Separation is required so one grounding electrode will not reduce the effectiveness of the other.

139 In dry areas and in soils with high resistivity, such as the volcanic tuff at LANL, backfill materials such as bentonite or coke breeze improve the performance of grounding electrodes. They do this through a combination of increasing the soil moisture content, decreasing the resistance of the electrode to soil interface, and increasing the effective diameter of the electrode.

[140] Refer to §4.2.1 in MIL-HDBK 1004/6.

[141] Refer to §250.106 in the 2002 NEC.

[142] Copper is the preferred lightning protection material because of its superior current-carrying capacity and fewer oxidation problems at connections compared to aluminum. Copper is much easier to work with and bends more easily than aluminum.

[143] Class I and Class II lightning protection conductors are manufactured using a special rope lay process that maximizes the surface area of the conductor and increases flexibility.

[144] Field inspection experience has shown a high failure rate of the finger style crimp connectors. The do not appear to provide adequate pullout resistance.

[145] Refer to paper titled "Lightning Rod Improvement Studies" by C. B. Moore, William Rison, James Mathis, and Graydon Aulich of the Langmuir Laboratory for Atmospheric Research, New Mexico Institute of Mining and Technology, Socorro, New Mexico published in *Journal of Applied Meteorology*: Vol. 39, No. 5, pp. 593–609. The results of this study suggest that moderately blunt metal rods (with tip height–to–tip radius of curvature ratios of about 680:1) are better lightning strike receptors than are sharper rods or very blunt ones

[146] 20-ft spacing allows use of air terminals that are shorter than 24 inches that do not require supplemental support. Refer to paragraph 3.6.2 in NFPA 780, 2000 Edition.

[147] Refer to §9.4.1 and §10.4.1 in UL 96A.

[148] Refer to §2.0d.3.(f) in Version 11C "IMPROVEMENTS TO THE DOE EXPLOSIVES SAFETY MANUAL" dated 4/18/02, voted and approved at the 46th DOE Explosives Safety Committee Meeting, 5/07/02. This requirement for explosives facilities is extended to all LANL facilities.

[149] NFPA 780 requires surge protection on electrical service entrances.

[150] Service entrance SPD ratings as recommended in Chapter 8 of IEEE Std. 1100-1999.

[151] IEEE Std 1100 recommended practice is to protect power and data circuits serving exterior equipment.

[152] Inadequate surge protection and grounding of alarm systems is a significant cause of maintenance and operational problems at LANL.

[153] NFPA 780 requires surge protection on radio and television antenna lead-ins.